AFIT/GEE/ENV/94S-27

A QUANTITATIVE METHOD FOR SCREENING POLLUTION PREVENTION PROGRAM OPTIONS AT UNITED STATES AIR FORCE INSTALLATIONS

THESIS

Wayne M. Williams, Captain, USAF

AFIT/GEE/ENV/94S-27

AFIT/GEE/ENV/94S-27

A QUANTITATIVE METHOD FOR SCREENING POLLUTION PREVENTION PROGRAM OPTIONS AT UNITED STATES AIR FORCE INSTALLATIONS

THESIS

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

Air Force Education and Training Command

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in

Engineering and Environmental Management

Wayne M. Williams, B.S.

Captain, USAF

September 1994

Approved for public release; distribution unlimited

The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the United States Government.

Acknowledgements

This research required a great deal of support from a number of individuals. Those deserving special recognition for their contributions include my thesis advisor, Major James R. Aldrich, and my thesis reader, Professor Dan Reynolds. Both of these individuals provided valuable guidance and insight throughout the entire research process.

I would be remiss if I did not also note that valuable moral support for this endeavor was provided by the remaining faculty of the AFIT Department of Environmental Management, and also by my thirty-four classmates. Without their encouragement this final report might never have been written.

Table of Contents

List of Tables

List of Figures

Abstract

In response to the requirements of the Pollution Prevention Act of 1990, US Air Force Installations worldwide have implemented pollution prevention (PP) programs designed to reduce the release of pollutants to the environment. Following guidance produced by the United States Environmental Protection Agency (USEPA), the Air Force uses Opportunity Assessments (OAs) to identify and evaluate waste producing processes that could benefit from a PP project. The OA process guidance provides extensive details on how to identify potential projects and on how to economically evaluate a project selected for implementation. However, while it recognizes that only a few of the identified projects can be thoroughly evaluated, the guidance provides only cursory information about how to decide which projects should be selected for this evaluation. This thesis bridges that gap by providing a quantitative model to be used for economic screening of potential pollution prevention opportunities by USAF installations.

The model developed in this thesis is a simplified version of the economic analysis process described in the OA guidance. It requires a user to collect data on a small number of project costs and perform a simple economic computation using that data. The result is a figure which estimates the potential economic benefit or loss of a project. This figure can be used to screen out projects which might be economically poor, enabling a base to focus its money and efforts on studying those projects with the greatest potential for economic benefit.

A QUANTITATIVE METHOD FOR SCREENING POLLUTION PREVENTION PROGRAM OPTIONS AT UNITED STATES AIR FORCE INSTALLATIONS

I. Introduction

Problem Description

In November of 1990 the United States Congress passed the Pollution Prevention Act. This law clearly stated that the elimination of pollution would be the principal component of the country's effort to clean up its environment. In response to the new legislation, the US Air Force (USAF) developed and initiated a pollution prevention policy which was formalized with Air Force Policy Directive 19-4 in 1992. This policy dictated that all Air Force installations would be held responsible for creating and managing their own pollution prevention (PP) programs (Dept. of the Air Force, 1992: 1).

In trying to establish their respective pollution prevention programs, many Air Force installations were faced with a similar problem -- how to implement as many pollution prevention projects as possible within the constraints of a limited budget. The usual approach to this problem has been to use the Environmental Protection Agency's (EPA) opportunity assessment (OA) process to identify and then implement those projects which are easiest to execute and have the greatest economic benefits.

Unfortunately, the OA process can often be difficult, time-consuming, and expensive. On top of that, the OA process can waste valuable time, money, and effort analyzing projects which turn out to be economically unsound. In the face of these obstacles the question is, is there a way to identify cost-effective pollution prevention projects without the lengthy analysis time, excessive costs, and extraneous results?

The answer to this is simple -- projects should be screened before being subjected to the OA process. Screening out projects which are not technically feasible, don't help attain organizational goals, or are not cost effective will reduce the costs and time required for an OA and eliminate unnecessary analyses. The EPA recommends screening as an integral part of the OA process for these very reasons; however, the EPA does not indicate how a user should conduct this screening process. Thus it is clear that while screening should be a part of any pollution prevention opportunity assessment process there are no guidelines as to how to best go about it.

Unfortunately, without clear guidelines, screening processes can be overlooked, ignored, or conducted improperly at many Air Force Bases. There is evidence of this in opportunity assessment reports from various Air Force bases, in which all potential projects at these bases are fully evaluated. The results of this are difficult to estimate, but it is probable that many bases have conducted expensive and time-consuming analyses of numerous projects only to determine that they are not feasible for implementation. For example, in an OA conducted at Hill Air Force Base, 35% of the 109 projects evaluated were found to be economically unsound (Engineering Science Inc., 1993). A reliable screening process would have identified those projects as poor ones before they were subjected to the full analysis, and thus reduced the amount of money and time invested in the OA.

To help correct this situation, this research proposes a method which can be effectively used to screen projects so as to minimize the costs and time associated with the OA process, and to ensure that valuable resources are only expended studying those projects which are most likely to benefit the Air Force.

Purpose and Objectives

The purpose of this study is to develop a quantitative technique that can be used to screen potential pollution prevention projects prior to selecting them for a detailed analysis. The following research objectives have been established to aid in accomplishing this purpose:

1. Determine cost categories that are significant contributors to the potential economic impact of a PP option and which are not.

2. Develop a simple technique using those significant cost categories for screening pollution prevention projects prior to a detailed economic assessment.

3. Evaluate the technique.

Scope and Limitations

This study focuses strictly on screening for cost-effectiveness. Other screening criteria, such as technical feasibility, waste reduction, and goal attainment are separate issues which are not dealt with in this thesis. While economic considerations should be the primary criteria used for selecting pollution prevention projects for detailed study, these other criteria may need to be considered at the discretion of the decision makers.

II. Background

History

Over the course of the past twenty years, the United States Congress has passed sweeping laws in an attempt to control and clean up the millions of tons of hazardous wastes produced in the US each year. Heavy penalties were imposed on businesses and individuals, including government employees, who were caught violating those laws. However, by 1990 studies revealed that the problem had not diminished significantly. Technologies for treating and disposing of hazardous wastes were simply not adequate for dealing with the quantity of wastes produced in the US. For example, although landfills have been a generally accepted method for disposing of hazardous wastes, a 1990 study by the US Environmental Protection Agency (EPA) showed that a majority of US landfills were no longer effectively containing the wastes they were built to hold (Hazardous Waste News, 1990). This led to the conclusion that the so-called 'end-of-pipe' controls advocated since the 1970's were not effective, and a different method of hazardous waste control was needed. The obvious choice was pollution prevention.

Once the need for a change was realized, Congress passed the Pollution Prevention Act of 1990. This law contained a number of provisions, but the most important of them spelled out in no uncertain terms the new philosophy for waste control:

> The Congress hereby declares it to be the national policy of the United States that pollution should be prevented or reduced at the source whenever feasible; pollution that cannot be prevented should be recycled in an environmentally safe manner, whenever feasible; pollution that cannot be prevented or recycled should be treated in an environmentally safe manner, whenever feasible; and disposal or other release into the environment should be employed only a last resort and should be conducted in an environmentally safe manner. (United States Congress, 1990: 1)

Clearly, the goal of Congress was to get the nation to think of preventing pollution first, and only after exhausting all pollution prevention possibilities could the accepted methods of treatment and disposal be used.

As part of the Pollution Prevention Act, Congress tasked the EPA with developing guidelines to help the nation's businesses and government facilities implement PP programs. To this end, the EPA established an information clearinghouse to collect and disseminate information on PP issues, initiated research projects to explore PP technologies, and distributed new guidelines for hazardous waste control emphasizing pollution prevention (EPA, 1992). One result of their efforts was a renewed emphasis on a process called opportunity assessment (OA).

The Opportunity Assessment Process

First developed in 1988 as part of the *Manual for Waste Minimization Opportunity Assessments*, the EPA's opportunity assessment process is a method for identifying and analyzing potential waste minimization options at a business or similar facility (EPA, 1988). It was initially intended to help companies improve their compliance with the 1984 Resource Conservation and Recovery Act, and so it focused primarily on land-based hazardous waste issues. After the Pollution Prevention Act was passed the EPA reworked the OA process to incorporate air and water based issues as well, and redistributed the guidance in the 1992 *Facility Pollution Prevention Guide*.

The EPA guidance on the OA process is extensive, but it can be summarized by the four-step process shown in Table 1 below (EPA, 1988: 4; EPA, 1992: 12 - 16).

The first step, PRELIMINARY ASSESSMENT, involves the selection of experts to form an assessment team, which then surveys installation activities and constructs a list of potential pollution prevention projects which could reduce or eliminate some wastes. In the next step, SCREENING, installation officials use subjective criteria to

Table 1 -- The EPA's Opportunity Assessment Process

STEP 1	STEP 2	STEP 3	STEP 4
PRELIMINARY ASSESSMENT	**SCREENING**	**ANALYSIS**	**IMPLEMENTATION**
Form assessment team. Survey installation activities. List possible PP projects.	Screen list. Select some projects for further study.	Perform in-depth analysis on projects selected in Step 2. Select projects for step 4.	Implement pollution prevention projects on waste streams selected in Step 3.

review the list from Step 1, and then they select some of the projects for further study. The third step, ANALYSIS, includes an in-depth economic study of each project selected in the screening step. Those with the greatest potential economic benefits are then recommended for the final step, IMPLEMENTATION.

Screening

In the *Facility Pollution Prevention Guide*, the EPA provides little direction as to how to screen pollution prevention projects. It offers a list of questions which should be considered and states that "screening procedures can range from an informal review with a decision made by either the program manager or a vote of the team members, to the use of quantitative decision-making tools" (EPA, 1992), which doesn't tell the user very much about how to screen projects. However, this statement does seem to imply that the use of "quantitative decision-making tools" is the most preferable screening option, and thus their use should provide a better screening process. Thus it is reasonable to assume that if an installation had such a quantitative tool then it would be able to conduct an effective screening process.

Air Force Guidance

In response to the 1990 Pollution Prevention Act, the Air Force developed and initiated a comprehensive pollution prevention policy which was formalized with Air

Force Policy Directive 19-4 in 1992. This policy clearly stated that all Air Force installations would be held responsible for creating and managing their own PP programs (Dept. of the Air Force, 1992: 1). Guidance on how this was to be done was provided in the US Air Force Installation Pollution Prevention Program Manual (EA Engineering, Science, and Technology, Inc., 1992). This manual, which is still the primary resource for Air Force PP programs, is based largely on the previously mentioned EPA documents, the *Manual For Waste Minimization Opportunity Assessments* and the *Facility Pollution Prevention Guide*. However, while it does specifically address the Air Force perspective on pollution prevention, it does not offer any significant deviations from the EPA's guidance on OAs. Hence the problem of insufficient guidance for the opportunity assessment process, particularly that dealing with the screening phase, was not addressed or corrected by published Air Force procedures. The presence of this problem gives rise to an increased potential for the unnecessary waste of resources. In these days of continually shrinking budgets, those resources are more valuable than ever, and the Air Force simply cannot afford to tolerate such practices any longer.

The Air Force Materiel Command Perspective

The Air Force Materiel Command (AFMC) is the USAF major command responsible for depot-level maintenance and repair of all Air Force aircraft and for other support functions such as vehicle maintenance and battery shop operations. In performing its mission, AFMC generates over 80 percent of the Air Force's hazardous wastes, and as such the command is very interested in employing pollution prevention strategies to reduce those wastes. To facilitate this, AFMC initiated opportunity assessments at all of its bases, starting in 1992. In this respect, AFMC has demonstrated that it is determined to be the Air Force leader in pollution prevention, despite limited funding.

However, in December 1993 AFMC published a review of the completed OAs which revealed that there were some problems with the OAs which necessitated further work. The review, done by AFMC's environmental directorate, stated in one of its findings that AFMC needed to "develop a Command-wide standardized method for completing opportunity assessments" (Air Force Materiel Command, 1993: 34), and that as part of that method, "a Total Life Cycle Cost Analysis should be performed for proposed pollution prevention options which involve significant commitments of Air Force dollars" (Air Force Materiel Command, 1993: 34). These deficiencies clearly are not unique to AFMC, but they are both problems inherent to the opportunity assessment process. AFMC's need to deal with these problems lends further support to the need for this research.

One of the OAs, performed at Hill AFB, Utah, was singled out by the study because it contained a detailed economic analysis while the remaining OAs contained only limited cost data. The Hill AFB OA provided base leaders with not only valuable technical information, but critical economic data that provided a sound basis for their project implementation decisions. The fact that only one of AFMC's sixteen installations spent the money for a detailed economic assessment leads one to suspect that in trying to save dollars many bases chose not to include economic evaluations in the OAs they conducted. This is potentially dangerous, because without complete information projects that could cost the Air Force money in the long run might be selected for implementation.

Building the Screening Model

Having established that the Air Force is in need of a screening tool for its OA processes, it is now necessary to explore how that tool should be constructed.

As mentioned previously, one purpose of screening pollution prevention projects is to identify those which are economically sound and those which are not. This purpose is essentially the same as that of a detailed economic assessment performed in Step 3 of an OA, except that an economic analysis is complex with many inputs, while a screening process should be simple and require only a few inputs. It is reasonable to assume then that a screening process and an economic analysis process might both employ similar methods to accomplish their similar purposes, differing only in complexity and level of effort. With that in mind, this research approaches the construction of a screening process by starting with the economic analysis process and working to remove complexity and effort while retaining the result. Having said that, it then becomes necessary to describe the economic analysis process.

Economic Analysis

The EPA currently recommends use of a technique called Total Cost Assessment (TCA), also known as Life Cycle Costing, for conducting the detailed economic analysis phase of the opportunity assessment (EPA, 1992: 59). TCA considers all possible costs of a project throughout the entire economic 'life' of that project. It recognizes the fact that the up-front purchase price of a project is not always representative of the total cost of that project, and so other costs, such as those related to operations and maintenance, labor, training, and disposal, are considered in TCA.

The first and most important step of TCA is the selection of the cost categories to be considered in the analysis. For pollution prevention projects, R.T. McHugh has identified four tiers of potential costs which should be considered in any TCA analysis of a PP project (EPA, 1993: 5-6):

Tier 0: Direct costs, such as capital costs, procurement costs, labor costs, and waste disposal costs.

Tier 1: Indirect costs, such as administrative costs, insurance costs, analytical costs, and training costs.

Tier 2: Liability costs, such as penalties for non-compliance, fines, and potential cleanup costs.

Tier 3: Intangible costs, such as employee relations, changes in public image, and corporate relationships.

Once the costs categories are identified and the actual costs are determined, TCA employs economic tools to evaluate those costs over a long period of time. Air Force Pamphlet 178-8, "Economic Analysis Procedures Handbook", recommends use of present value/net present value procedures for performing this evaluation.

Present Value/Net Present Value. Present Value is an economic tool that takes into account the fact that money in hand now is worth more than money received in the future, due to the power of money to earn interest over time. Mathematically it can be calculated using the following equation:

$$PV = \frac{F}{(1+r)^n} \tag{1}$$

where PV is the present value, F is the future value, r is the interest rate, and n is the number of periods. The Net Present Value (NPV) is simply the sum of the present values of each of the payments. The following example shows how this is computed.

Consider a process which currently costs a base $20,000 per year to operate. Assume that this process will only be necessary for the next three years. This produces the payment stream shown in Figure 1 below. (Down arrows represent costs; up arrows would indicate benefits.)

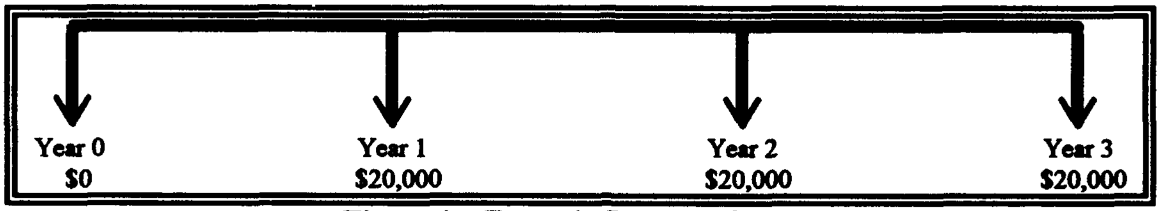

Figure 1. Example Payment Stream

Assume that the applicable interest rate is 10% - this is the standard figure recommended in government cost estimating guidance (Dept. of the Air Force, 1988), and assume that the interest is only compounded once per year. Using this information and equation 3.1, present values can be calculated for each of the payments as follows:

$$PV_{year0} = \frac{\$0}{(1+.10)^0} = \$0 \tag{2}$$

$$PV_{year1} = \frac{-\$20,000}{(1+.10)^1} = -\$18181.81 \tag{3}$$

$$PV_{year2} = \frac{-\$20,000}{(1+.10)^2} = -\$16528.92 \tag{4}$$

$$PV_{year3} = \frac{-\$20,000}{(1+.10)^3} = -\$15026.29 \tag{5}$$

Simply summing the four present values yields the net present value, -$49,737.02. This figure represents the amount which, if placed in a bank in year 0 at 10% interest, would cover all costs of the current process over its three year life.

Measuring Economic Soundness

The purpose of any economic analysis is to indicate the *economic soundness* of the project or projects being studied. Economic soundness is a measure of how good or bad a project is when compared economically with the current mode of operation. If the project is expected to cost less or earn more money than the current process, then it is considered economically sound. If the project is expected to cost more or earn less money than the current process, than it is considered economically unsound. The basic indicator of economic soundness is the Net Present Value (NPV). Typically, any project with an NPV greater than zero is considered economically sound, and any project with an NPV less than zero is considered economically unsound. However, in practice, there will most likely be a range around zero (i.e. 0 ± $10,000) in which a user may consider other factors such as available funds and quality of cost data to make a subjective judgment of economic soundness. While this range is subjective, one feasible way of specifying it is to relate it to the project investment cost. For example, a base may decide that a project is acceptable if its NPV indicates a return of at least 10% of its investment cost over its life, it will be unacceptable if its NPV indicates a loss of more than 10% of its investment cost over its life, and if its NPV falls between those two values then the project may warrant further study.

The Screening Model Defined

In order for the proposed screening model to be useful, it must meet two criteria. First, it must effectively indicate economic soundness. Since the model will be derived from the Total Cost Assessment process, this requirement will undoubtedly be met. It's effectiveness can be measured by applying the model to projects which have already been economically analyzed, and calculating the number of times the model correctly indicates the economic soundness. The model does not need to be 100%

effective. It should, however, be effective enough that it correctly indicates economic soundness a majority of the time.

The second criteria is that the model must require a minimum of effort to use. This implies that the model must use as little data as possible, therefore the number of cost categories providing input to the model must be minimized. In order to maintain a high degree of effectiveness, the cost categories which are used in the screening model must be those which have the greatest impact on economic soundness. These cost categories are hereafter called the *most significant categories*, and the next chapter will describe the process by which they are identified.

Data Collection

In order to properly develop a screening tool from the economic analysis process, it is necessary to have some data. With the aid of personnel at ProAct, an Air Force environmental research office located at the Air Force Center for Environmental Excellence, Brooks AFB, Texas, a search was conducted for reports from completed opportunity assessments at US Air Force bases. While the search turned up a number of reports, only one contained any usable economic data. This report, from Hill AFB, was obtained and used as the database for this research.

Hill Air Force Base

Hill Air Force Base, Utah, is home to the Ogden Air Logistics Center, a depot-level maintenance facility designed to conduct complete refurbishing of F-16, F-4, and C-130 aircraft, Peacekeeper and Minuteman missile systems, and landing gear for all Air Force weapons systems. In addition to this, Hill AFB performs its regular Air Force base operations and maintenance missions, including vehicle operations, civil engineering, and support of active duty F-16 aircraft. Overall, these activities generate more than 250 different hazardous waste streams, producing approximately 100 different types of waste. This diversity of missions makes Hill AFB representative of AFMC bases, and the types of projects studied at Hill AFB are representative of those likely to be found at other AFMC bases.

The Hill AFB Opportunity Assessment

The Hill AFB opportunity assessment was performed by Engineering Science Inc. (ESI), an independent engineering consulting company working on a government contract. The OA was initiated in March 1992, and was completed in May 1993. ESI's first step was to collect and organize data on over 250 waste-producing processes at Hill AFB. Projects were then screened for technical feasibility, and similar projects at different locations were lumped together. This reduced the number of projects considered to 125. ESI then undertook a comprehensive economic analysis of those 125 projects. As additional data was collected during this phase some projects were combined or eliminated from consideration, and in the end complete economic analyses were produced on 109 PP projects. These economic analyses each considered 15 different cost categories which could impact a pollution prevention project. The following sections briefly describe these cost categories.

Process Equipment Costs. The cost of any new equipment required to implement the pollution prevention project.

Construction Materials Costs. The costs of any necessary materials required to facilitate installation of new equipment or facilities associated with the PP project. This category was broken down into four sub-categories: Piping costs, Electrical Materials costs, Instrument costs, and Structural Materials costs.

Utility Connections/Systems Costs. The costs of any necessary increases in usage of utility connections or systems as part of the PP project. This category was broken down into eight sub-categories: Electrical, Steam, Cooling Water, Process Water, Refrigeration, Fuel (Gas or Oil), Plant Air, and Inert Gas.

Site Preparation Costs. The costs associated with any necessary preparations or improvements made to the site of the PP project.

Installation Costs. The costs associated with the installation of any equipment required by the PP project. This category was broken down into three sub-categories: Vendor costs, Contractor costs, and In-House Staff costs.

Training Costs. The costs incurred as a result of increases in worker training necessitated under the PP project.

Engineering Costs. The costs of designing new facilities or systems required to support the PP project.

Start-Up Costs. The costs associated with initial startup of new systems required by the PP project. This category was broken down into three subcategories: Vendor costs, Contractor costs, and In-House Staff costs.

Permitting Costs. The cost of obtaining new permits necessitated by the PP project. This category was broken down into two sub-categories: Fees and In-House Staff Costs.

Input Material Costs. The costs of material inputs to the process being changed under the PP project.

Salvage Value. Actually a financial gain, this category is tracked as a negative cost. It contains benefits realized from the sale of materials and equipment made available under the PP project. This category was broken down into two sub-categories: Equipment benefits and Materials benefits.

Disposal Costs. The costs associated with the handling, transportation, treatment, and disposal of wastes generated by the process being considered under the PP project. This category was broken down into four sub-categories: TSDF Fees, On-Site

Treatment Costs, On-Site Storage and Handling Costs, and Permitting and Reporting Costs.

Research and Development Costs. The costs associated with the development of new technologies to be used as part of the PP project.

Other Operations and Maintenance Costs. The costs associated with the day-to-day operation and maintenance of the equipment and systems which are part of the process being considered under the PP project. This category was broken down into four sub-categories: Labor costs, Supplies costs, Analytical costs, and Miscellaneous O&M Costs.

By-Product Recovery Value. Actually a financial gain, this category is tracked as a negative cost. It contains benefits realized from the sale or reuse of by-products recovered as part of the process being considered under the PP project.

A sample computation sheet from the full economic analysis performed by Engineering Science Corp. is attached at Appendix A.

There are other categories which, according to McHugh, should have been included in the analysis. Among them are liability costs, medical costs, emergency response costs, and others. Unfortunately, since these were not included in the Hill AFB OA, no data for these cost categories is available. It is possible that data for these categories would impact the results of this study, but without data it is impossible to draw any conclusions in that respect. If additional data does become available, this may warrant further study.

III. Methodology

Introduction

This thesis uses a straightforward process to develop the screening model, summarized with the flowchart in Figure 2 below. In Step 1, some basic data analysis tools are employed to determine which of the cost categories are most significant. Then, in Step 2, a Net Present Value is calculated for each of the 109 projects in the dataset using only the most significant cost category. In Step 3 these new NPVs are then compared with the actual project NPVs, and a determination is made as to whether the new NPVs accurately indicate the economic soundness of the projects or not. If not, then in Step 4 another significant cost category is added, and Steps 2, 3, and 4 are repeated until enough cost categories are included in the model to accurately indicate economic soundness. The remainder of this chapter contains more detailed discussions on each of these steps.

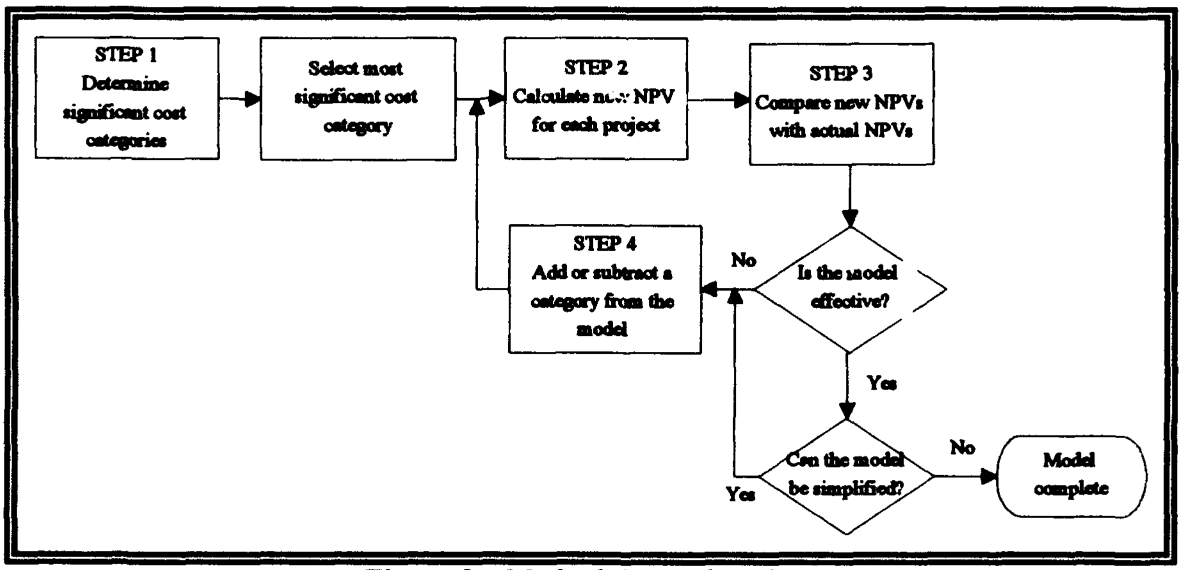

Figure 2. Methodology Flowchart

Exploratory Data Analysis

The initial intent of this thesis was to use linear regression techniques to determine the "best" economic analysis model which could be used to indicate the economic soundness of a pollution prevention project. However, after brief inspection it was evident that regression methods were not appropriate because the "best" model was already known; it is simply the Total Cost Assessment model which the EPA already recommends for this purpose. Thus the need arose for an alternative approach to the problem. The method chosen was exploratory data analysis.

The Encyclopedia of Statistical Sciences describes exploratory data analysis (EDA) as "the attitude, approach, and techniques ... for flexible probing of data before any probabilistic model is available." (Kotz, et al., 1982) As such, it is generally the first contact with a dataset during an analysis. Its purpose is to employ any of a number of techniques to identify patterns, distributions, relationships, and abnormalities in the data, and reveal them in a way which is readily apparent to the analyst and other observers. The focus of an EDA is on finding evidence of the existence of a probabilistic model. One of the key aspects of exploratory data analysis is that it is very flexible. An analyst can choose to employ only those techniques which are most appropriate for the data, and as patterns are revealed within the data the choice of techniques may be altered to fit the changing situation.

There are four general themes in exploratory data analysis: resistance, residuals, re-expression, and display. (Kotz, et.al., 1982) The first two are not used in this thesis and thus are not explained here. The third theme, re-expression, involves the mathematical transformation of the raw data to a scale which facilitates the analysis. The most common form of re-expression is the logarithmic transformation, (Kotz, et al), but in this thesis a linear transformation will be used. The fourth theme of EDA, display, is concerned with the use of graphical techniques to visually reveal the features of the data.

EDA techniques will be used in this thesis to examine, transform, and visually assess the data collected by Hill Air Force Base. The goal of the EDA is to identify any cost categories which are more significant than others, build them into a potential screening model, and evaluate that model's effectiveness at indicating economic soundness.

Determining Relative Significance of the Cost Categories

Significant cost categories are those which make the greatest contributions to the economic soundness of a project. The significance of a cost category is best measured by figuring what portion of the total cost is contributed by each category. For example, consider Project A, which is being evaluated using three cost categories: Equipment, which is a $15,000 investment (up-front) cost, Materials, which is a $10,000 annual cost, and Labor, which is a $25,000 annual cost. Assuming a 3-year economic life for this project, the present values of these cost categories are calculated to be -$15,000 for Equipment, -$24,868.52 for Materials, and -$62,171.30 for Labor. The total cost is the sum of these present values, or -$102,039.82. The portion of the total cost contributed by Equipment is -$15,000/-$102,039.82, or .147. Similarly, the portion contributed by Materials is .244, and the portion contributed by Labor is .609. Of these three categories, Labor is the most significant, due to its greater contribution to the total cost, and conversely, Equipment is the least significant category.

In this thesis, these proportional contributions will be multiplied by 100 to convert them to percentages, and these new figures will be referred to as *percentage contributions*. Percentage contributions are useful because they can be easily be compared from one project to another. For example, consider Project B, which is evaluated using the same three cost categories as Project A above. In this case, Equipment costs are $50 up front, Materials costs are $40 per year, and Labor costs are $10 per year. Present values for these costs are -$50 for Equipment, -$99.47 for Materials, and -$24.86 for Labor, yielding a total project cost of -$174.33. Thus the percentage contribution of Equipment is 28.68%, Materials is 57.06%, and Labor is 14.26%. Comparing project A to project B on the basis of dollars alone does not reveal much (i.e. Equipment is -$15,000 in Project A and -$50 in Project B. In which project is it more significant?). Using percentage contribution figures for comparison clearly indicates which cost categories are more significant within each project (Labor in Project A, Materials in Project B), and which project a category is more significant in (Materials is more significant in Project B than in Project A).

Percentage contributions have been calculated for each of the fifteen cost categories in each of the 109 projects of the Hill AFB dataset. These percentage contributions were averaged for each cost category across all 109 projects, resulting in a set of values representing the percentage contributions of each cost category for an "average" project. The cost category with the greatest average percentage contribution is considered the most significant category. The one with the second greatest average percentage contribution is the next most significant, and so on through all fifteen categories. The result of this is a listing of all cost categories in order from greatest to least significance, which is presented in the next chapter. This thesis presumes that upon inspection some cost categories will clearly be much more significant than others, and only these "most significant" cost categories will be used in developing a screening model.

Calculation and Comparison of NPVs

Once the relative significance of the cost categories has been determined, the model development continues by selecting the most significant cost category and calculating a new NPV for each project using only the data from that cost category. For example, using the figures for project A above, Labor is seen to be the most significant cost category. Using just the Labor costs, and assuming the same 3-year economic life for the project, a payment stream is developed consisting of $0 in year 0 and costs of $25,000 in each of years 1, 2, and 3. The NPV of this payment stream is -$62,171.30.

Once calculated, each new NPV is then compared with the actual NPV of its respective project, which was calculated using all of the available cost categories. Recall from Chapter II that when measuring economic soundness, a project's NPV can fall into one of three regions of economic soundness -- economically sound, unsound, or questionable (See Figure 3 below). For purposes of this research, the questionable region is defined as 0 ± 20% of the project investment cost. For example, if the project being screened requires a $1000 investment up front, then the questionable range of economic soundness is between $200 and -$200, and thus projects with NPVs greater than $200 are economically sound and projects with NPVs less than -$200 are economically unsound. If the new NPV and actual NPV both fall into the same region of economic soundness, then the new NPV correctly indicates the economic soundness of the project and is declared a *match*. If the new NPV falls into a different region of economic soundness than the actual NPV, then the new NPV does not indicate the economic soundness of the project and a *mismatch* results.

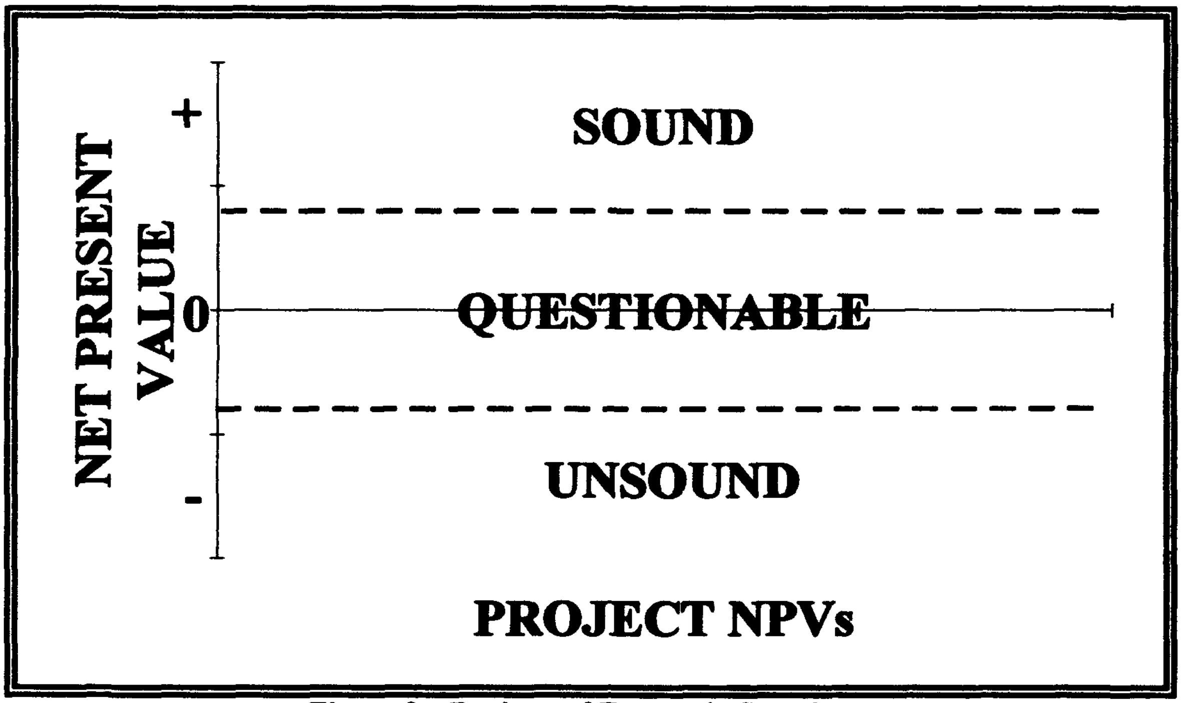

Figure 3. Regions of Economic Soundness

In order to properly assess the effectiveness of the model, this comparison must be repeated for a number of projects, and the total number of matches determined. The model's effectiveness is then calculated by dividing the number of matches by the total number of projects. For example, if 100 projects were being evaluated using a particular model, and after comparing NPVs computed using the model with the actual project NPVs a total of 85 matches were found, the model's effectiveness would be calculated as 85/100 or 85%. If the effectiveness is not judged to be high enough, then further significant cost categories may be added to the model until the desired effectiveness is achieved. When adding further cost categories to the model does not improve effectiveness enough to justify the increase in data collection workload associated with those additional cost categories, then no further cost categories need be included and the model is complete.

IV. Analysis

Relative Significance of Cost Categories

The data from the Hill AFB study contains cost information for 15 cost categories in each of 109 potential pollution prevention projects. This information is summarized in the listing attached at Appendix B. Using the procedures outlined in the previous chapter, this cost data was easily converted to percentage contributions by dividing the value of each of the cost categories by the total cost for each project. The resulting dataset is also included in Appendix B.

From the percentage contribution dataset, a simple arithmetic average was calculated for each of the 15 cost categories across all 109 projects, and the resulting list is then ordered from largest to smallest average percentage contribution. Shown graphically, this list appears as shown in Figure 4 below.

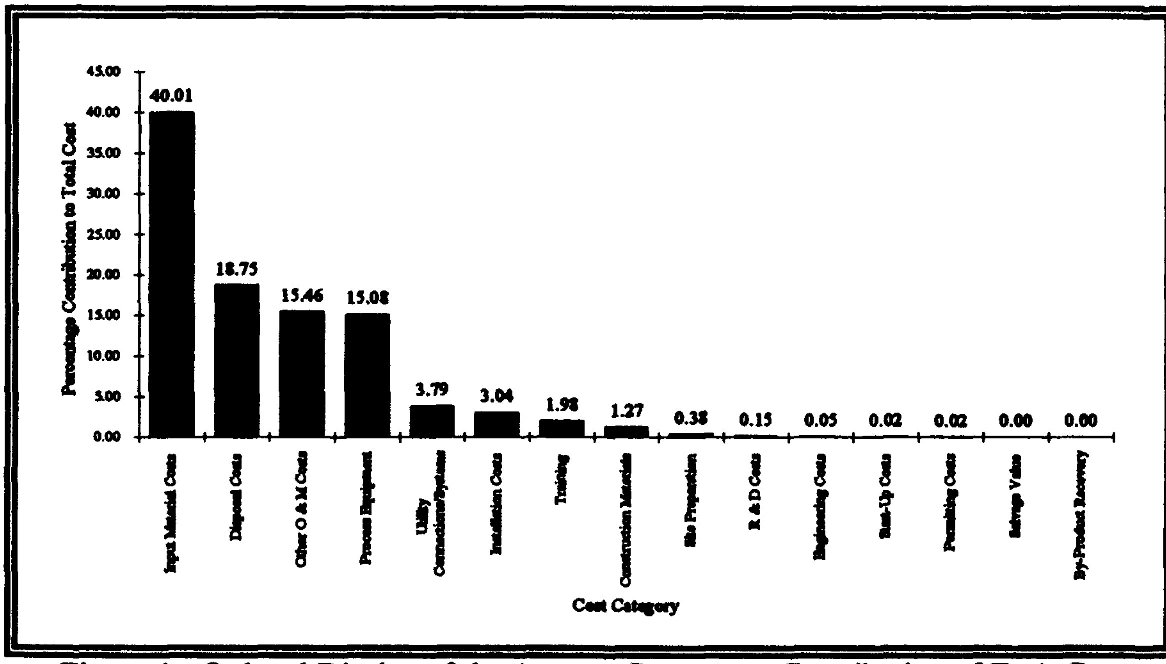

Figure 4. Ordered Display of the Average Percentage Contribution of Each Cost Category to Total Project Cost

As described in the previous chapter, the cost category with the largest average percentage contribution is considered the most significant cost category. Similarly, the category with the next greatest percentage contribution is the second most significant cost category, and so on down to the category with the smallest percentage contribution which is considered least significant. Figure 3 clearly shows that Input Materials is the most significant cost category. The graph also shows that Disposal Costs, Other O&M Costs, and Equipment Costs are also fairly significant. In fact, these four cost categories alone contribute 89.30% of the total project cost, on average. The remaining eleven cost categories combine for the final 10.7%, and are relatively insignificant.

Calculations and Comparisons

Following the methods described in Chapter III, an initial model was built consisting solely of the most significant cost category, Input Material Costs. Then, using only the data from this cost category, a new NPV for each of the 109 projects was calculated. These new NPVs were then compared with the actual NPVs for each of the projects, the number of matches determined, and the model effectiveness calculated, as described in Chapter III. In this case, using just the most significant cost category, a total of 64 matches was achieved, for an effectiveness of 59.72%.

Adding further significant cost categories improved the effectiveness of the screening model (see Table 2 below). Including a second cost category yielded a model with an effectiveness of 72.48%, adding a third category increased effectiveness to 81.65%, adding a fourth improved it to 90.83%, and adding a fifth category improved effectiveness to 93.58%.

Table 2. Summary of Model Effectiveness

Cost Categories Included	Matches	Effectiveness
Input Materials	64	59.72%
Input Materials, Disposal	79	72.48%
Input Materials, Other O&M	79	72.48%
Input Materials, Process Equipment	69	63.30%
Input Materials, Disposal, Other O&M	89	81.65%
Input Materials, Disposal, Process Equipment	84	77.06%
Input Materials, Other O&M, Process Equipment	84	77.06%
Input Materials, Disposal, Other O&M, Process Equipment	99	90.83%
Input Materials, Disposal, Other O&M, Process Equipment, Construction	101	92.66%
Input Materials, Disposal, Other O&M, Process Equipment, Installation	101	92.66%
Input Materials, Disposal, Other O&M, Process Equipment, Training	102	93.58%
Input Materials, Disposal, Other O&M, Process Equipment, Utilities	100	91.74%

Figure 5 shows how the effectiveness of the model increased as further cost categories were added. Because including additional cost categories in the screening model requires more data, it therefore requires more work to implement. Since that is exactly the work that this screening model is intended to avoid, it was desirable to limit

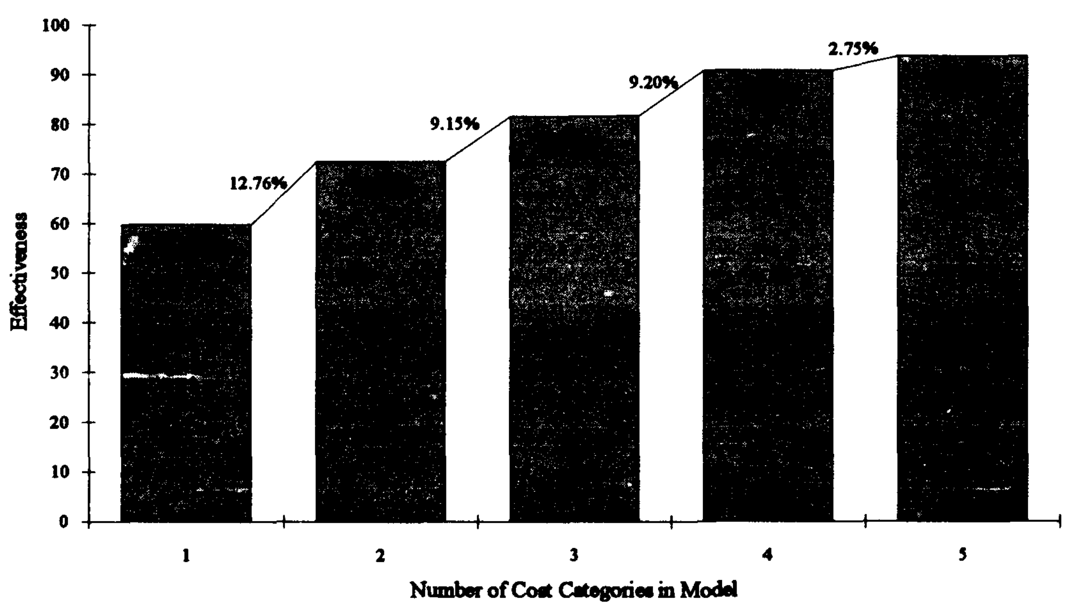

Figure 5. Improvements in Effectiveness Achieved by Adding Cost Categories

the number of cost categories used in the model. However, it was also desirable to build a screening model with a high level of effectiveness. The balance between the two was achieved by adding cost categories to the model until the addition of further cost categories did not increase effectiveness enough to warrant the increase in the data collection workload. Figure 5 shows that adding up to four cost categories to the model resulted in a significant improvement in model effectiveness at each increment, but when the fifth cost category was added a much smaller increase was achieved. Because this fifth cost category contributed so much less to the effectiveness of the model than the other four cost categories, it did not make any significant improvement to the model and therefore its inclusion did not justify the increased data collection it would require. Thus the fifth cost category was not added, and the final model indicated by this research contained only the following four cost categories: Input Materials, Disposal, Other O&M, and Process Equipment.

Sensitivity

The four-cost model selected here only indicated 90.83% of the Hill AFB projects correctly. The model indicated the remaining 9.17% (10 projects) as shown in Table 3 below.

Table 3. Summary Information for Incorrectly Indicated Projects

Indicated	Actual		# Projects	Percentage
Sound	Unsound	False Positive	Four	3.67%
Sound	Questionable	False Positive	One	0.92%
Questionable	Unsound	Acceptable	Four	3.67%
Unsound	Sound	False Negative	One	0.92%

As the Table shows, five projects were indicated as being sound when they were not, resulting in a 4.59% false positive error rate. This is significant because false positives will generally result in the expenditure of money and time implementing pollution prevention projects which will eventually lose money. Four projects were indicated as questionable when unsound, which is acceptable because it is assumed that these projects would be studied further and more information will correctly reveal the project's true economic soundness. This avoids the loss of funds involved in implementing thes unsound projects, but does not avoid the expense of extensive study. Finally, only one project reported a false negative error, indicating that only a small number of good pollution prevention opportunites will be missed by this model.

Discussion

The results of this simple yet revealing analysis indicate that it is possible to predict, with better than 90% effectiveness, the economic soundness of a pollution prevention project using a model containing only four cost categories. If a lesser degree of effectiveness can be tolerated, a model containing even fewer cost categories can be used, which requires less data and thus simplifies the work needed to implement a model. The ability to predict the economic soundness of a project is valuable as this knowledge can be used to help ensure that only projects with economic benefits are selected for a costly detailed study.

V. Summary

Research Summary

This research set out to develop a technique which can quickly and easily provide a reliable estimate of the economic soundness of a pollution prevention project. In chapter II the need for this technique was described along with some necessary background information. In Chapter III the processes used to develop this technique were discussed, and in Chapter IV an actual technique was developed and evaluated. The final result of this work is that its intended goal was achieved, and a working technique has been provided. By employing this technique in their pollution prevention programs, US Air Force Installations can effectively screen their pollution prevention projects as specified in the existing guidance for the opportunity assessment process.

Benefits Of This Technique

The biggest benefit of using the technique developed in this thesis is that it provides a way for an Air Force Installation to identify the economic soundness of its pollution prevention projects earlier in the opportunity assessment process. This gives that installation the opportunity to begin implementing the economically sound projects sooner, reveals those economically unsound projects which should be deleted from the pollution prevention program, and then only perform full economic analyses on the questionable projects. The technique can also be used by a base to perform an independent check on any economic analyses performed by a contractor. Finally, in cases where bases have for one reason or another opted not to perform economic analysis of their pollution prevention projects, this technique offers a simple method which could provide them with some limited yet reliable economic information on which to base their decisions.

Recommendations For Further Study

There are two specific areas in which this research can be studies further:

Collect additional data and validate/refute the technique. The dataset used to develop this screening technique contained information from only one Air Force base. Because most Air Force bases contain similar facilities and perform the same operations, it is not unreasonable to assume that a screening tool that works at one base would work at any of the other bases. However, in order to be certain that this is a valid assumption, additional cost data from a different Air Force base should be collected, if it's available, and used to test this screening technique more thoroughly.

Examine the impact of missing cost categories. The data used in this research was collected by a contractor in accordance with specifications provided by Hill Air Force Base. It considered only the costs categories listed in AFR 173-15, "Economic Analysis and Program Evaluation for Resource Management", which was released by the Air Force in 1988. Since then, new research has indicated that cost categories not listed in AFR 173-15, such as medical costs, liability costs, and public image costs, may be significant costs which should be considered when evaluating pollution prevention projects. Information on these costs was not contained in the Hill AFB data, and so was not considered in the development of the screening technique. It is conceivable that, if data on these costs categories had been available, the results of this research may have been different. Further study could determine if this is true or not.

APPENDIX A

Hill Air Force Base Data Sample

Appendix A: Hill Air Force Base Data Sample

General Assumptions

The following are some general assumptions made by the Engineering Science engineers during their opportunity assessment of Hill Air Force Base.

1. Net Present Worth analysis is used for comparing projects.

2. The discount rate of 7% was provided by the Hill AFB Financial Management Directorate.

3. The economic life is equal to the physical or technical life. Therefore, no salvage life is assumed at the end of the economic life.

4. The average personnel salary at Hill AFB is $41,551, which equates to $20/hour. This figure was also provided by the Hill AFB Financial Management Directorate.

5. There are approximately 245 working days per year with 8-hour shifts.

6. All personnel are 100% productive. Therefore, any projects requiring personnel activity (i.e. installation, training, etc.) assume a labor cost of $20/hour.

7. Additional assumptions may be made for specific projects. These additional assumptions are listed with their supporting calculations in Appendix A of the Opportunity Assessment report.

Page 33 contains a sample data sheet from one of the 109 projects evaluated at Hill AFB which were used for this research. The following paragraphs contain explanations of some of the entries and calculations on the sample data sheet.

1. Base Costs. Operating and Investment costs for the current operation. Operating costs are on an annual basis. Investment costs will normally be zero. Costs are shown as a positive value.

2. Project Investment Costs. Capital costs required to purchase equipment, train personnel, etc. Costs are shown as a positive value. The differential cost is the project investment cost subtracted from the base (current) investment cost. A negative differential cost value indicates the additional cost for the project.

3. Project Operating Costs. Annual operating costs required if the project is implemented. A positive value indicates a cost. The differential cost is the project operating cost subtracted from the base (current) operating cost. A positive differential cost value indicates an annual cost savings for the project.

4. Present Value of Project. Calculated using a 7% discount factor, the economic life, and the total operating costs and investment costs for the affected cost elements. Shown as a positive cost value. No differential costs are used for calculating this value. Present value of project is used to calculate the contribution of each cost category to the total project cost. These values are shown for all 109 projects in Appendix II.

5. Percent of Cost. The percentage of the project's total present worth contributed by each cost category. These values are shown for all 109 projects in Appendix II.

6. Total Investment Cost. Total capital required to implement project.

7. Total Annual Operating Costs/Savings. Total annual savings or costs if project is implemented. Positive value indicates an annual savings. Negative value indicates an additional cost to the current process costs.

8. Payback Period. The total investment cost (6) divided by the total annual costs/savings (7). This value indicates the number of years required to recoup the initial investment costs of the project.

9. Net Present Value. The present value of the total net annual operating costs/savings over the economic life of the project minus the total investment costs. Shown as a positive costs savings value.

Option # 20

Title: Precelan Parts With Steam Cleaner
Economic Life: 10 Years
Payback: 5.45 Years
Process: DST
NPV: $13,085

Cost Element:	Base Cost Operating	Base Cost Investment	Investment Costs Unit Cost	Investment Costs # Units	Investment Costs Cost	Investment Costs Diff Cost	Operating Costs Unit Cost	Operating Costs # Units	Operating Costs Cost	Operating Costs Diff Cost	Present Value	% of Cost
Process Equipment	$0	$0	$2,000.00	20.00	$40,000	($40,000)	$0.00	0.00	$0	$0	$40,000	10.58
Construction Materials												
Piping	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
Electrical	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
Instruments	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
Structural	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
Utility Connections/Systems												
Electricity	$0	$0	$0.00	0.00	$0	$0	$0.03	20000.00	$600	($600)	$4,214	1.11
Steam	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
Cooling Water	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
Process Water	$0	$0	$0.00	0.00	$0	$0	$0.70	1760.00	$1,232	($1,232)	$8,653	2.29
Refrigeration	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
Fuel (Gas or Oil)	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
Plant Air	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
Inert Gas	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
Site Preparation	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
Installation Costs												
Vendor	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
Contractor	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
In-House Staff	$0	$0	$20.00	120.00	$2,400	($2,400)	$0.00	0.00	$0	$0	$2,400	0.63
Training	$0	$0	$20.00	150.00	$3,000	($3,000)	$20.00	10.00	$200	($200)	$4,405	1.16
Engineering Costs	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
Start-Up Costs												
Vendor	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
Contractor	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
In-House Staff	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
Permitting Costs												
Fees	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
In-House Staff	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
Input Material Costs	$4,775	$0	$0.00	0.00	$0	$0	$1.91	1500.00	$2,865	$1,910	$20,123	5.32
Salvage Value												
Equipment	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
Recovered Materials	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
Disposal Costs												
TSDF Fees	$13,000	$0	$0.00	0.00	$0	$0	$1.04	7500.00	$7,800	$5,200	$54,784	14.48
On-Site Treatment	$0	$0	$0.00	0.00	$0	$0	$8.52	1400.00	$11,928	($11,928)	$83,777	22.15
On-Site Storage/Handling	$7,941	$0	$0.00	0.00	$0	$0	$158.80	30.00	$4,764	$3,177	$33,460	8.85
Permitting/Reporting/Etc	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
R & D Costs	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
Other O & M Costs												
Labor	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
Supplies	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
Analytical Costs	$30,000	$0	$0.00	0.00	$0	$0	$750.00	24.00	$18,000	$12,000	$126,424	33.42
Miscellaneous	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
By-Product Recovery	$0	$0	$0.00	0.00	$0	$0	$0.00	0.00	$0	$0	$0	0.00
TOTALS	$55,716	$0			$45,400	($45,400)			$47,389	$8,327	$378,241	100.00

APPENDIX B

Summary of Project Cost Data and Percentage Contribution Data

APPENDIX B: Summary of Project Cost Data and Percentage Contribution Data

	Project 1	Project 2	Project 3	Project 4	Project 5
Process Equipment	$0	$13,000	$0	$0	$4,200
	0.00%	99.80%	0.00%	0.00%	10.60%
Construction Materials	$0	$0	$0	$0	$0
	0.00%	0.00%	0.00%	0.00%	0.00%
Utility Connections/Systems	$0	$7	$18,432	$0	$152
	0.00%	0.06%	3.66%	0.00%	0.38%
Site Preparation	$0	$0	$0	$0	$0
	0.00%	0.00%	0.00%	0.00%	0.00%
Installation Costs	$0	$1	$0	$0	$0
	0.00%	0.01%	0.00%	0.00%	0.00%
Training	$0	$1	$9,463	$80	$480
	0.00%	0.01%	1.88%	1.11%	1.21%
Engineering Costs	$0	$0	$0	$0	$0
	0.00%	0.00%	0.00%	0.00%	0.00%
Start-Up Costs	$0	$0	$0	$0	$160
	0.00%	0.00%	0.00%	0.00%	0.40%
Permitting Costs	$0	$0	$0	$0	$0
	0.00%	0.00%	0.00%	0.00%	0.00%
Input Material Costs	$0	$16	$251,802	$6,258	$24,393
	0.00%	0.12%	49.96%	87.15%	61.59%
Salvage Value	$0	$0	$0	$0	$0
	0.00%	0.00%	0.00%	0.00%	0.00%
Disposal Costs	$693	$0	$224,314	$0	$10,222
	100.00%	0.00%	44.51%	0.00%	25.81%
R & D Costs	$0	$0	$0	$0	$0
	0.00%	0.00%	0.00%	0.00%	0.00%
Other O & M Costs	$0	$0	$0	$843	$0
	0.00%	0.00%	0.00%	11.74%	0.00%
By-Product Recovery	$0	$0	$0	$0	$0
	0.00%	0.00%	0.00%	0.00%	0.00%
Total cost over life:	$693	$13,026	$504,011	$7,181	$39,607

APPENDIX B: Summary of Project Cost Data and Percentage Contribution Data

Project 6	Project 7	Project 8	Project 9	Project 10	Project 11	Project 12
$9,181 25.61%	$0 0.00%	$5,371 19.06%	$6,809 7.44%	$23,000 71.56%	$1,500 1.89%	$0 0.00%
$0 0.00%	$0 0.00%	$0 0.00%	$17,749 19.39%	$0 0.00%	$0 0.00%	$0 0.00%
$2 0.00%	$0 0.00%	$616 2.19%	$0 0.00%	$341 1.06%	$165 0.21%	$0 0.00%
$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%
$160 0.45%	$0 0.00%	$0 0.00%	$2,616 2.86%	$0 0.00%	$320 0.40%	$0 0.00%
$480 1.34%	$5,968 12.36%	$320 1.14%	$0 0.00%	$160 0.50%	$1,680 2.12%	$51,000 2.60%
$0 0.00%	$0 0.00%	$0 0.00%	$2,010 2.20%	$0 0.00%	$0 0.00%	$0 0.00%
$160 0.45%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%
$0 0.00%	$0 0.00%	$0 0.00%	$664 0.73%	$0 0.00%	$0 0.00%	$0 0.00%
$25,854 72.11%	$42,303 87.58%	$7,628 27.07%	$61,689 67.39%	$0 0.00%	$8,639 10.88%	$1,263,690 64.32%
$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%
$18 0.05%	$32 0.07%	$6 0.02%	$0 0.00%	$0 0.00%	$46,007 57.96%	$576,133 29.33%
$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%
$0 0.00%	$0 0.00%	$14,235 50.52%	$0 0.00%	$8,639 26.88%	$21,071 26.54%	$73,748 3.75%
$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%
$35,854	$48,304	$28,176	$91,536	$32,140	$79,382	$1,964,571

APPENDIX B: Summary of Project Cost Data and Percentage Contribution Data

Project 13	Project 14	Project 15	Project 16	Project 17	Project 18	Project 19
$16,881	$0	$0	$0	$180,000	$54,000	$40,000
1.98%	0.00%	0.00%	0.00%	52.85%	15.38%	10.73%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$101,107	$33,452	$0
0.00%	0.00%	0.00%	0.00%	29.69%	9.53%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$1,800	$4,320	$1,600
0.00%	0.00%	0.00%	0.00%	0.53%	1.23%	0.43%
$0	$0	$5,100	$29,271	$8,809	$0	$0
0.00%	0.00%	6.81%	8.55%	2.59%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$360	$0	$20	$0	$0	$0	$0
0.04%	0.00%	0.03%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$836,445	$857,579	$0	$26,690	$42,141	$247,230	$39,192
97.98%	58.60%	0.00%	7.80%	12.37%	70.40%	10.51%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$591,459	$50,257	$117,659	$1,134	$6,583	$117,988
0.00%	40.42%	67.07%	34.38%	0.33%	1.87%	31.64%
$0	$14,400	$0	$0	$5,600	$5,600	$5,600
0.00%	0.98%	0.00%	0.00%	1.64%	1.59%	1.50%
$0	$0	$19,553	$168,566	$0	$0	$168,566
0.00%	0.00%	26.09%	49.26%	0.00%	0.00%	45.20%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$853,686	$1,463,439	$74,930	$342,186	$340,592	$351,184	$372,946

APPENDIX B: Summary of Project Cost Data and Percentage Contribution Data

Project 20	Project 21	Project 22	Project 23	Project 24	Project 25	Project 26
$40,000 10.58%	$54,000 27.10%	$0 0.00%	$18,000 4.88%	$27,450 15.05%	$135,000 37.64%	$142,875 55.96%
$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%
$12,867 3.40%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$17,383 4.85%	$0 0.00%
$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%
$2,400 0.63%	$2,160 1.08%	$0 0.00%	$0 0.00%	$2,160 1.18%	$1,800 0.50%	$1,800 0.70%
$4,405 1.16%	$8,809 4.42%	$0 0.00%	$0 0.00%	$8,809 4.83%	$8,809 2.46%	$8,809 3.45%
$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%
$0 0.00%	$0 0.00%	$0 0.00%	$2,160 0.59%	$0 0.00%	$0 0.00%	$0 0.00%
$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%
$20,123 5.32%	$11,134 5.59%	$30,201 96.92%	$272,603 73.92%	$90,868 49.82%	$16,769 4.68%	$60,578 23.73%
$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%
$172,022 45.48%	$49,421 24.80%	$0 0.00%	$50,191 13.61%	$16,730 9.17%	$73,537 20.50%	$11,153 4.37%
$0 0.00%	$0 0.00%	$0 0.00%	$5,600 1.52%	$5,600 3.07%	$0 0.00%	$5,600 2.19%
$126,424 33.42%	$73,748 37.01%	$960 3.08%	$20,228 5.49%	$30,763 16.87%	$105,354 29.37%	$24,512 9.60%
$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%
$378,241	$199,272	$31,161	$368,781	$182,380	$358,652	$255,329

APPENDIX B: Summary of Project Cost Data and Percentage Contribution Data

Project 27	Project 28	Project 29	Project 30	Project 31	Project 32	Project 33
$0	$120,000	$82,875	$0	$0	$28,500	$200,000
0.00%	69.79%	6.33%	0.00%	0.00%	7.01%	51.56%
$0	$0	$0	$0	$60,177	$0	$0
0.00%	0.00%	0.00%	0.00%	4.78%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$17,699
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.56%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$1,800	$1,800	$0	$0	$1,800	$14,480
0.00%	1.05%	0.14%	0.00%	0.00%	0.44%	3.73%
$5,728	$1,282	$1,282	$0	$2,564	$1,282	$0
0.48%	0.75%	0.10%	0.00%	0.20%	0.32%	0.00%
$0	$0	$0	$6,400	$0	$0	$0
0.00%	0.00%	0.00%	0.53%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$639,398	$42,141	$998,859	$639,432	$639,432	$201,112	$2,585
53.18%	24.51%	76.26%	53.15%	50.78%	49.44%	0.67%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$388,601	$1,122	$125,576	$388,601	$388,601	$121,438	$0
32.32%	0.65%	9.59%	32.30%	30.86%	29.85%	0.00%
$0	$5,600	$5,600	$0	$0	$0	$0
0.00%	3.26%	0.43%	0.00%	0.00%	0.00%	0.00%
$168,566	$0	$93,765	$168,566	$168,566	$52,677	$153,114
14.02%	0.00%	7.16%	14.01%	13.39%	12.95%	39.47%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$1,202,293	$171,945	$1,309,756	$1,202,999	$1,259,340	$406,808	$387,878

APPENDIX B: Summary of Project Cost Data and Percentage Contribution Data

Project 34	Project 35	Project 36	Project 37	Project 38	Project 39	Project 40
$0	$22,000	$0	$31,500	$1,150,000	$415,500	$3,780,000
0.00%	34.61%	0.00%	98.81%	66.41%	64.11%	21.90%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$97,052	$0	$13,298,969
0.00%	0.00%	0.00%	0.00%	5.60%	0.00%	77.04%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$21,000	$0	$300	$80,500	$100,000	$112,980
0.00%	33.04%	0.00%	0.94%	4.65%	15.43%	0.65%
$0	$1,600	$0	$80	$480	$36,400	$0
0.00%	2.52%	0.00%	0.25%	0.03%	5.62%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$427,034	$18,964	$427,034	$0	$18,121	$0	$0
34.08%	29.83%	43.68%	0.00%	1.05%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$8,923	$0	$13,589
0.00%	0.00%	0.00%	0.00%	0.52%	0.00%	0.08%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$825,973	$0	$550,649	$0	$376,464	$96,223	$55,837
65.92%	0.00%	56.32%	0.00%	21.74%	14.85%	0.32%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$1,253,007	$63,564	$977,683	$31,880	$1,731,539	$648,123	$17,261,376

APPENDIX B: Summary of Project Cost Data and Percentage Contribution Data

Project 41	Project 42	Project 43	Project 44	Project 45	Project 46	Project 47
$2,030,000	$2,800	$2,800	$46,000	$0	$0	$0
54.46%	64.54%	4.20%	2.15%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$1,496,639	$0	$702	$0	$0	$0	$0
40.15%	0.00%	1.05%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$150,000	$0	$7,000	$4,600	$0	$0	$0
4.02%	0.00%	10.50%	0.22%	0.00%	0.00%	0.00%
$480	$0	$0	$3,200	$0	$100	$0
0.01%	0.00%	0.00%	0.15%	0.00%	2.07%	0.00%
$0	$0	$0	$0	$200	$0	$0
0.00%	0.00%	0.00%	0.00%	0.70%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$183	$42,844	$192,727	$28,417	$3,463	$61,239
0.00%	4.21%	64.24%	9.03%	99.30%	71.74%	53.36%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$1,243	$12,783	$1,888,501	$0	$0	$53,537
0.00%	28.66%	19.17%	88.45%	0.00%	0.00%	46.64%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$50,570	$112	$562	$0	$0	$1,264	$0
1.36%	2.59%	0.84%	0.00%	0.00%	26.19%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$3,727,689	$4,338	$66,691	$2,135,028	$28,617	$4,827	$114,775

APPENDIX B: Summary of Project Cost Data and Percentage Contribution Data

Project 48	Project 49	Project 50	Project 51	Project 52	Project 53	Project 54
$0	$2,000	$0	$110,000	$0	$2,594	$0
0.00%	2.68%	0.00%	100.00%	0.00%	10.83%	0.00%
$0	$0	$18,700	$0	$6,966	$0	$0
0.00%	0.00%	13.57%	0.00%	63.52%	0.00%	0.00%
$0	$64	$104,935	$0	$0	$500	$0
0.00%	0.09%	76.16%	0.00%	0.00%	2.09%	0.00%
$0	$0	$2,000	$0	$4,000	$0	$0
0.00%	0.00%	1.45%	0.00%	36.48%	0.00%	0.00%
$0	$562	$800	$0	$0	$0	$0
0.00%	0.75%	0.58%	0.00%	0.00%	0.00%	0.00%
$0	$562	$0	$0	$0	$560	$160
0.00%	0.75%	0.00%	0.00%	0.00%	2.34%	1.50%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$126,969	$71,575	$0	$0	$0	$3,433	$0
100.00%	95.74%	0.00%	0.00%	0.00%	14.33%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$7,839	$0	$0	$4,335	$0
0.00%	0.00%	5.69%	0.00%	0.00%	18.10%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$3,500	$0	$0	$12,530	$10,535
0.00%	0.00%	2.54%	0.00%	0.00%	52.31%	98.50%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$126,969	$74,763	$137,775	$110,000	$10,966	$23,952	$10,695

<u>APPENDIX B: Summary of Project Cost Data and Percentage Contribution Data</u>

Project 55	Project 56	Project 57	Project 58	Project 59	Project 60	Project 61
$470 0.05%	$0 0.00%	$0 0.00%	$6,552 9.04%	$0 0.00%	$400 62.17%	$450 -0.94%
$0 0.00%	$0 0.00%	$0 0.00%	$1,100 1.52%	$0 0.00%	$0 0.00%	$0 0.00%
$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$18 2.18%	$15 2.41%	$0 0.00%
$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%
$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$40 6.22%	$120 -0.25%
$240 0.02%	$0 0.00%	$0 0.00%	$660 0.91%	$580 71.33%	$140 21.76%	$0 0.00%
$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%
$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%
$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%
$99,215 10.32%	$84,182 100.00%	$405 6.25%	$30,287 41.77%	$0 0.00%	$0 0.00%	$0 0.00%
$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	($50,833) 106.49%
$1,838 0.19%	$0 0.00%	$4,845 74.88%	$10,038 13.84%	$215 26.49%	$48 7.44%	$0 0.00%
$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%
$859,686 89.42%	$0 0.00%	$1,221 18.87%	$23,880 32.93%	$0 0.00%	$0 0.00%	$2,528 -5.30%
$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%	$0 0.00%
$961,450	$84,182	$6,470	$72,517	$813	$643	($47,734)

APPENDIX B: Summary of Project Cost Data and Percentage Contribution Data

Project 62	Project 63	Project 64	Project 65	Project 66	Project 67	Project 68
$3,975	$0	$0	$0	$11,963,200	$4,149,600	$4,149,600
-15.56%	0.00%	0.00%	0.00%	43.68%	25.94%	25.41%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$28	$0	$0	$33,856	$2,705,415	$1,381,488	$1,711,632
-0.11%	0.00%	0.00%	23.16%	9.88%	8.64%	10.48%
$0	$0	$0	$0	$80,000	$80,000	$80,000
0.00%	0.00%	0.00%	0.00%	0.29%	0.50%	0.49%
$80	$0	$0	$0	$4,540,000	$1,037,600	$1,037,600
-0.31%	0.00%	0.00%	0.00%	16.58%	6.49%	6.35%
$0	$0	$0	$0	$97,036	$97,036	$97,036
0.00%	0.00%	0.00%	0.00%	0.35%	0.61%	0.59%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$30,287	$30,287	$30,287
0.00%	0.00%	0.00%	0.00%	0.11%	0.19%	0.19%
$31,284	$95,679	$91,613	$320	$122,410	$1,249,606	$1,249,606
-122.47%	50.29%	49.00%	0.22%	0.45%	7.81%	7.65%
($60,910)	$0	$0	$0	$0	$0	$0
238.45%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$94,359	$95,139	$112,022	$4,876,377	$4,996,674	$4,996,674
0.00%	49.60%	50.89%	76.62%	17.80%	31.23%	30.60%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$214	$214	$0	$2,975,373	$2,975,373	$2,975,373
0.00%	0.11%	0.11%	0.00%	10.86%	18.60%	18.22%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
($25,544)	$190,252	$186,966	$146,199	$27,390,099	$15,997,665	$16,327,809

APPENDIX B: Summary of Project Cost Data and Percentage Contribution Data

Project 69	Project 70	Project 71	Project 72	Project 73	Project 74	Project 75
$7,040,000	$7,482,400	$2,560,000	$0	$380,240	$0	$0
37.97%	36.42%	11.32%	0.00%	1.64%	0.00%	0.00%
$0	$0	$0	$0	$7,650,648	$0	$0
0.00%	0.00%	0.00%	0.00%	33.03%	0.00%	0.00%
$1,910,257	$1,216,817	$11,563,408	$0	$0	$0	$0
10.30%	5.92%	51.12%	0.00%	0.00%	0.00%	0.00%
$80,000	$80,000	$80,000	$0	$0	$0	$0
0.43%	0.39%	0.35%	0.00%	0.00%	0.00%	0.00%
$1,408,000	$2,256,000	$316,000	$0	$0	$8,000	$0
7.59%	10.98%	1.40%	0.00%	0.00%	100.00%	0.00%
$97,036	$97,036	$97,036	$150,417	$646,987	$0	$0
0.52%	0.47%	0.43%	0.74%	2.79%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$1,600
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.93%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$30,287	$30,287	$30,287	$0	$0	$0	$0
0.16%	0.15%	0.13%	0.00%	0.00%	0.00%	0.00%
$122,410	$1,396,935	$122,410	$17,781,472	$13,188,187	$0	$169,680
0.66%	6.80%	0.54%	87.86%	56.93%	0.00%	99.07%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.97%	0.00%	0.00%
$4,876,377	$5,008,114	$4,876,377	$2,306,397	$1,299,080	$0	$0
26.30%	24.38%	21.56%	11.40%	5.61%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$2,975,373	$2,975,373	$2,975,373	$0	$0	$0	$0
16.05%	14.48%	13.15%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$18,539,741	$20,542,963	$22,620,892	$20,238,286	$23,165,142	$8,000	$171,280

APPENDIX B: Summary of Project Cost Data and Percentage Contribution Data

Project 76	Project 77	Project 78	Project 79	Project 80	Project 81	Project 82
$5,133,600	$0	$0	$1,960,000	$0	$0	$0
26.15%	0.00%	0.00%	1.81%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$671,071	$0	$0	$331,295	$0	$0	$0
3.42%	0.00%	0.00%	0.31%	0.00%	0.00%	0.00%
$80,000	$0	$0	$0	$0	$0	$0
0.41%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$1,026,400	$0	$0	$0	$0	$0	$0
5.23%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$97,036	$0	$0	$0	$0	$0	$16,047
0.49%	0.00%	0.00%	0.00%	0.00%	0.00%	1.36%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$30,287	$0	$0	$0	$0	$0	$0
0.15%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$4,143,008	$30,009,692	$1,264,245	$102,029,848	$9,828,863	$0	$417,201
21.10%	99.41%	37.50%	94.24%	89.21%	0.00%	35.24%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$4,876,377	$0	$1,630,826	$1,979,611	$1,189,113	$2,646,640	$645,411
24.84%	0.00%	48.37%	1.83%	10.79%	26.44%	54.51%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$3,573,435	$177,477	$476,199	$1,962,410	$0	$7,362,905	$105,354
18.20%	0.59%	14.13%	1.81%	0.00%	73.56%	8.90%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$19,631,215	$30,187,169	$3,371,270	$108,263,164	$11,017,977	$10,009,545	$1,184,012

APPENDIX B: Summary of Project Cost Data and Percentage Contribution Data

Project 83	Project 84	Project 85	Project 86	Project 87	Project 88	Project 89
$0	$5,600	$0	$0	$0	$19,775	$1,908
0.00%	0.17%	0.00%	0.00%	0.00%	3.28%	1.54%
$0	$0	$0	$0	$0	$3,525	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.59%	0.00%
$0	$0	$0	$0	$0	$3,715	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.62%	0.00%
$0	$0	$0	$0	$0	$198	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.00%
$0	$0	$0	$0	$0	$800	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.13%	0.00%
$800	$0	$80	$0	$0	$320	$180
1.11%	0.00%	3.72%	0.00%	0.00%	0.05%	0.15%
$0	$0	$0	$0	$0	$800	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.13%	0.00%
$0	$0	$0	$80	$0	$320	$0
0.00%	0.00%	0.00%	0.88%	0.00%	0.05%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$71,453	$3,282,260	$2,073	$9,035	$46,131	$255,729	$38,818
98.89%	99.79%	96.28%	99.12%	47.96%	42.47%	31.33%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$1,317	$0	$0	$48,126	$155,601	$23,422
0.00%	0.04%	0.00%	0.00%	50.04%	25.84%	18.91%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$1,924	$161,332	$59,560
0.00%	0.00%	0.00%	0.00%	2.00%	26.79%	48.08%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$72,253	$3,289,177	$2,153	$9,115	$96,180	$602,114	$123,888

APPENDIX B: Summary of Project Cost Data and Percentage Contribution Data

Project 90	Project 91	Project 92	Project 93	Project 94	Project 95	Project 96
$0	$67,843	$1,908	$0	$41,379	$1,272	$0
0.00%	61.39%	1.62%	0.00%	21.55%	3.47%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$10,600	$0	$0	$100,000	$0	$0
0.00%	9.59%	0.00%	0.00%	52.08%	0.00%	0.00%
$0	$720	$180	$0	$720	$120	$0
0.00%	0.65%	0.15%	0.00%	0.37%	0.33%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$70,638	$6,807	$28,783	$57,748	$8,378	$9,181	$18,214
55.59%	6.16%	24.43%	48.98%	4.36%	25.04%	50.08%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$16,730	$4,461	$16,730	$13,384	$5,577	$5,577	$4,461
13.17%	4.04%	14.20%	11.35%	2.90%	15.21%	12.27%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$39,704	$20,073	$70,236	$46,777	$35,961	$20,509	$13,697
31.25%	18.17%	59.60%	39.67%	18.73%	55.95%	37.66%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$127,073	$110,504	$117,837	$117,909	$192,014	$36,658	$36,373

APPENDIX B: Summary of Project Cost Data and Percentage Contribution Data

Project 97	Project 98	Project 99	Project 100	Project 101	Project 102	Project 103
$37,446	$636	$0	$20,432	$0	$0	$0
59.43%	1.36%	0.00%	45.63%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$5,850	$0	$0	$3,000	$0	$0	$0
9.28%	0.00%	0.00%	6.70%	0.00%	0.00%	0.00%
$480	$60	$0	$160	$6,300	$0	$0
0.76%	0.13%	0.00%	0.36%	25.49%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$4,407	$19,373	$34,207	$9,285	$979	$1,464	$1,118
6.99%	41.39%	72.78%	20.74%	3.96%	77.94%	72.96%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$3,346	$12,269	$7,807	$5,577	$892	$414	$414
5.31%	26.21%	16.61%	12.45%	3.61%	22.06%	27.04%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$11,477	$14,469	$4,987	$6,321	$16,543	$0	$0
18.22%	30.91%	10.61%	14.12%	66.94%	0.00%	0.00%
$0	$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$63,006	$46,807	$47,001	$44,775	$24,715	$1,878	$1,532

APPENDIX B: Summary of Project Cost Data and Percentage Contribution Data

Project 104	Project 105	Project 106	Project 107	Project 108	Project 109
$0	$0	$6,967	$0	$22,500	$0
0.00%	0.00%	0.21%	0.00%	4.54%	0.00%
$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$536	$0	$36,440	$160,003
0.00%	0.00%	0.02%	0.00%	7.35%	7.56%
$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$1,686	$0
0.00%	0.00%	0.00%	0.00%	0.34%	0.00%
$0	$0	$1,200	$0	$2,809	$8,374
0.00%	0.00%	0.04%	0.00%	0.57%	0.40%
$0	$0	$12,800	$0	$0	$0
0.00%	0.00%	0.39%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$4,189	$3,495	$3,049,046	$4,663	$0	$0
92.70%	91.20%	93.32%	100.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$330	$337	$0	$0	$432,051	$1,947,463
7.30%	8.80%	0.00%	0.00%	87.20%	92.04%
$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$0	$0	$196,801	$0	$0	$0
0.00%	0.00%	6.02%	0.00%	0.00%	0.00%
$0	$0	$0	$0	$0	$0
0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
$4,519	$3,832	$3,267,349	$4,663	$495,486	$2,115,840

Bibliography

Air Force Materiel Command. Findings Report on Development of Prototype Pollution Prevention PPBS Funding Package for a Select Group of FY 95-96 Projects. Wright-Patterson AFB, OH, 1993.

Aldrich, James R. Pollution Prevention Economics. Unpublished manuscript. Air Force Institute of Technology, Wright-Patterson AFB, OH, 1993.

Department of the Air Force. Pollution Prevention. AF Policy Directive 19-4. Washington: GPO, 30 November 1992.

EA Engineering, Science, and Technology, Inc. U.S. Air Force Installation Pollution Prevention Program Manual. Sparks MD, January 1992.

Engineering Science, Inc. Pollution Prevention Process Assessment Draft Final Report. Contract F-3615-89-D-4003, Order 49. Unpublished report. Hill AFB, UT. May 1993.

Engineering Science, Inc. Economic Analysis Report for Pollution Prevention Process Assessment. Contract F-3615-89-D-4003, Order 49. Hill AFB, UT. March 1992.

Environmental Protection Agency. The EPA Manual for Waste Minimization Opportunity Assessments. EPA/600/2-88/025. Cincinnati OH: Office of Research and Development, April 1988.

Environmental Protection Agency. The EPA Facility Pollution Prevention Guide. EPA/600/R-92/088. Cincinnati OH: Office of Research and Development, May 1992.

Environmental Protection Agency. A Primer For Financial Analysis of Pollution Prevention Projects. EPA/600/R-93/059. Cincinnati, OH: Office of Research and Development, April 1993.

Hazardous Waste News. 23 April 1990.

Kotz, Samuel and others. "Exploratory Data Analysis," Encyclopedia of Statistical Sciences, Volume 2. New York: John Wiley and Sons, 1982

United States Congress. Pollution Prevention Act of 1990. Public Law No. 101-508, 101st Congress, 2nd Session. Washington: GPO, 1990.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)

2. REPORT DATE
September 1994

3. REPORT TYPE AND DATES COVERED
Master's Thesis

4. TITLE AND SUBTITLE
A QUANTITATIVE METHOD FOR SCREENING POLLUTION PREVENTION PROGRAM OPTIONS AT US AIR FORCE INSTALLATIONS

5. FUNDING NUMBERS

6. AUTHOR(S)
Wayne M. Williams, Captain, USAF

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Air Force Institute of Technology, WPAFB OH. 45433-6583

8. PERFORMING ORGANIZATION REPORT NUMBER
AFIT/GEE/ENV/94S-27

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

US Air Force installations worldwide are required to implement pollution prevention (PP) programs designed to reduce the release of pollutants to the environment, and the Air Force uses opportunity assessments (OAs) to identify and evaluate waste producing processes that could benefit from a PP project. The OA process guidance provides extensive details on how to identify potential projects and on how to economically evaluate a project selected for implementation. However, it provides only cursory information about how to decide which projects should be selected for this evaluation. This thesis bridges that gap by providing a quantitative model to be used for economic screening of potential pollution prevention opportunities by USAF installations. The model is a simplified version of the economic analysis process described in the OA guidance. It requires a user to collect data on a small number of project costs and perform a simple economic computation using that data. The result is a figure which estimates the potential economic benefit or loss of a project. This figure can be used to screen out projects which might be economically poor, enabling a base to focus its money and efforts on studying those projects with the greatest potential for economic benefit

14. SUBJECT TERMS
Pollution Prevention Economics, Opportunity Assessment

15. NUMBER OF PAGES
60

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89)
Prescribed by ANSI Std Z39-18
298-102

GENERAL INSTRUCTIONS FOR COMPLETING SF 298

The Report Documentation Page (RDP) is used in announcing and cataloging reports. It is important that this information be consistent with the rest of the report, particularly the cover and title page. Instructions for filling in each block of the form follow. It is important to ***stay within the lines*** to meet ***optical scanning requirements***.

Block 1. Agency Use Only *(Leave blank)*.

Block 2. Report Date. Full publication date including day, month, and year, if available (e.g. 1 Jan 88). Must cite at least the year.

Block 3. Type of Report and Dates Covered. State whether report is interim, final, etc. If applicable, enter inclusive report dates (e.g. 10 Jun 87 - 30 Jun 88).

Block 4. Title and Subtitle. A title is taken from the part of the report that provides the most meaningful and complete information. When a report is prepared in more than one volume, repeat the primary title, add volume number, and include subtitle for the specific volume. On classified documents enter the title classification in parentheses.

Block 5. Funding Numbers. To include contract and grant numbers; may include program element number(s), project number(s), task number(s), and work unit number(s). Use the following labels:

C	- Contract	**PR**	- Project
G	- Grant	**TA**	- Task
PE	- Program Element	**WU**	- Work Unit Accession No.

Block 6. Author(s). Name(s) of person(s) responsible for writing the report, performing the research, or credited with the content of the report. If editor or compiler, this should follow the name(s).

Block 7. Performing Organization Name(s) and Address(es). Self-explanatory.

Block 8. Performing Organization Report Number. Enter the unique alphanumeric report number(s) assigned by the organization performing the report.

Block 9. Sponsoring/Monitoring Agency Name(s) and Address(es). Self-explanatory.

Block 10. Sponsoring/Monitoring Agency Report Number. *(If known)*

Block 11. Supplementary Notes. Enter information not included elsewhere such as: Prepared in cooperation with...; Trans. of...; To be published in.... When a report is revised, include a statement whether the new report supersedes or supplements the older report.

Block 12a. Distribution/Availability Statement. Denotes public availability or limitations. Cite any availability to the public. Enter additional limitations or special markings in all capitals (e.g. NOFORN, REL, ITAR).

DOD - See DoDD 5230.24, "Distribution Statements on Technical Documents."
DOE - See authorities.
NASA - See Handbook NHB 2200.2.
NTIS - Leave blank.

Block 12b. Distribution Code.

DOD - Leave blank.
DOE - Enter DOE distribution categories from the Standard Distribution for Unclassified Scientific and Technical Reports.
NASA - Leave blank.
NTIS - Leave blank.

Block 13. Abstract. Include a brief *(Maximum 200 words)* factual summary of the most significant information contained in the report.

Block 14. Subject Terms. Keywords or phrases identifying major subjects in the report.

Block 15. Number of Pages. Enter the total number of pages.

Block 16. Price Code. Enter appropriate price code *(NTIS only)*.

Blocks 17. - 19. Security Classifications. Self-explanatory. Enter U.S. Security Classification in accordance with U.S. Security Regulations (i.e., UNCLASSIFIED). If form contains classified information, stamp classification on the top and bottom of the page.

Block 20. Limitation of Abstract. This block must be completed to assign a limitation to the abstract. Enter either UL (unlimited) or SAR (same as report). An entry in this block is necessary if the abstract is to be limited. If blank, the abstract is assumed to be unlimited.